Effect of Low Dose Gamma Radiation on Lipids in Five Different Meats

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ABSTRACT

Five types of meats were irradiated by gamma radiation up to a dose of 10 kGy. The m. longissimus dorsi *from pork, lamb and beef was irradiated as well as turkey leg and turkey breast muscle. After irradiation, the lipids were extracted from the muscles to ascertain the effect of irradiation. Peroxide and iodine values along with malonaldehyde concentration were used to assess any damage made to the lipids, and to note any significant differences in these compounds due to the type of muscle tissue. Peroxide and iodine values showed that at low irradiation dose, < 10 kGy, there was no significant change in any of the meat lipids. Malonaldehyde concentration changed significantly at the micromolar level due to irradiation dose, but only in turkey breast muscle.*

INTRODUCTION

The public expects that our food supply should be safer than it is today because food-borne illnesses continue to be a problem in the United States. It is estimated that 80 million cases of food illness occur each year and that these result in about 9000 deaths (Glosser *et al.*, 1994). Over the years, changes in farming practices and food processing have increased the complexity of the food distribution chain, which has opened new areas where pathogens can be introduced. Consequently, the country's food safety system needs to be modernized. One option is to improve food safety through food irradiation.

Food irradiation has been shown to be a wholesome process by many scientific studies conducted worldwide during the past 40 years (Radomyski *et al.*, 1994; Thayer, 1994, 1990). It is generally accepted by world health organizations that low level (< 10 kGy) food irradiation is safe (Loaharanu, 1994). Above 10 kGy there may be undesirable organoleptic changes, particularly to foods irradiated in the non-frozen state. Food irradiation extends shelf life, destroys pests and reduces illness from food-borne pathogens. Furthermore, the United States government is examining low level (< 10 kGy) food irradiation for red meats, as low level irradiation has already been approved for poultry (3 kGy maximum) and pork (1 kGy maximum).

The purpose of this study was to determine what effect, if any, low dose (< 10 kGy) gamma irradiation has on lipids in different types of meats. The premise was that all meats would be affected equally, i.e., meats as a generic food class were predicted to respond to irradiation dose in a similar manner and to produce similar chemical data from analogous meat components, provided that the conditions of irradiation were identical; a concept known as 'chemiclearance'. Peroxide value, iodine value, and malonaldehyde formation were measured to assess the effect of irradiation on meat lipids. These commonly used analytical methods measure the primary and secondary changes of lipid oxidation in meat and meat products (Gray & Monahan, 1992). Peroxide values have been used before in irradiated beef studies (Lefebvre *et al.*, 1994; Kosaric *et al.*, 1973) and malonaldehyde concentrations as measured by thiobarbituric acid (TBA) values have been used in a study on irradiated chicken (Heath *et al.*, 1992). Two questions were of interest here: (1) will dose-dependent radiolytic reactions occur with meat lipids at doses below 10 kGy; and (2) are meat lipids from different types of meats affected in the same manner? To answer these questions, five types of meats (pork, beef, lamb, turkey leg and turkey breast) were exposed to gamma radiation at various doses (approximately 0, 1, 3, 6, 10 kGy), their lipids extracted and the analyses conducted. To avoid bias due to animal variation, three independent lots of each meat were obtained at different times. Also the same muscle (*m. longissimus dorsi*) was used from the red meats (pork, lamb and beef).

MATERIALS AND METHODS

All meats were purchased locally, one day after slaughter. Pork was purchased from Leidy (Soudertown, PA), beef (steer) from Carl Venezia (Conshohocken, PA), lamb and turkey from C. Fehl's (Springhouse, PA). The extraction solvents, chloroform and methanol, were high purity, HPLC grade and obtained from Burdick and Jackson (Muskegon, MI). Deionized water was a laboratory preparation. All chemicals were reagent grade and obtained from J. T. Baker (Phillipsburg, NJ), Sigma (St Louis, MO), or Mallinckrodt (St Louis, MO). Sodium thiosulfate (0.1 normal) and Wijs (iodine monochloride) standard solutions were supplied by Red Bird Service (Osgood, IN). A Büchi Rotovapor model RE111 (Switzerland) was used to evaporate solvents. A Mettler model PM300 balance (Switzerland) was used to weigh samples to 0.01 g. Peroxide values were determined with a 10 ml burette calibrated to 0.05 ml. A spectrometer, model ABI 1000S Applied Biosystems, was used to measure malonaldehyde at a wavelength of 532 nm.

The meats used were the *m. longissimus dorsi* of the mammals and the breast and entire leg muscles of the turkey. In a cold room, all muscles were carefully trimmed of fat, cubed and frozen in dry ice. The frozen meat (1.4–5.2% fat) was then pulverized in a Hobart silent cutter to yield a homogeneous material. The meat powder was allowed to thaw, packaged (100 g lots) into Cryovac E poultry bags (air transmission 4000 cm^3/m^2 per 24 hr at 1 atm and 22.8°C) and hung from racks in the center of the radiation field for the irradiation process.

Gamma radiation

The gamma ray source was a ^{137}Cs built by Lockheed Corporation (Marietta, GA) operating at a strength of approximately 134,000 Ci and a dose rate of 0.108 kGy min^{-1}. The dose rate was established using National Physical Laboratory (Middlesex, UK) dosimeters. Dosimetry and dose distribution for the source have been described (Shieh *et al.*, 1985). The temperature of the radiation chamber was maintained at 5 ± 0.5°C during irradiation by injecting the gas phase from liquid nitrogen into the radiation chamber.

Sample temperature was monitored continuously during irradiation. The meat samples received doses of 0, 0.943, 2.83, 5.66 and 9.43 kGy.

Extraction

After irradiation, a portion of the meat samples (50–60 g) were extracted twice, each time with 100 ml of 2:1 chloroform/methanol solvent (Folch *et al.*, 1957). The meat solvent mixture was filtered through a Whatman number 2 (7 cm) filter paper using a Büchner funnel and a suction flask. The filtrate was transferred to a separation funnel, where it was mixed with 40 ml of 1% potassium chloride solution. After settling for 1 hr, the lower organic solvent layer was transferred to a round bottom flask and the solvent removed with the rotary evaporator. Traces of solvent remaining after evaporation to dryness were blown off with a stream of nitrogen. A portion, usually 0.1–0.4 g, was removed from the recovered lipid for iodine value determination.

Analyses

Peroxide and iodine values were determined on the recovered lipid by American Oil Chemists' Society Standard methods (Firestone, 1990): cd 8–53 for peroxide value and cd 1–25 for iodine value (Wijs method). A 3 g sample of meat was used to determine malonaldehyde by the thiobarbituric acid (TBA) method (Pikul *et al.*, 1989). Peroxide values were determined within hours of the irradiation. Samples for iodine value were stored in a refrigerator overnight under nitrogen and their iodine value determined the next morning. Malonaldehyde concentrations were determined the same day as the irradiation.

RESULTS AND DISCUSSION

The results are shown for peroxide value (PV) and iodine value (IV) determined on lipids extracted from five different meats exposed to gamma irradiation up to 10 kGy (Table 1). The data show the mean values and the standard deviations for each sample in triplicate. Notice that all the meat lipids, except turkey leg, had a peroxide value >0 before irradiation. The data show that over the dose range 0–10 kGy, there is no apparent increase in peroxide value with increasing dose. It has been reported that lean ground beef irradiated at 1, 2.5 and 5.0 kGy (Lefebvre *et al.*, 1994) showed a 9–12-fold increase in peroxide value over the non-irradiated meat. However, that study showed no difference among initial peroxide values owing to irradiation doses of 1, 2.5 and 5 kGy. Upon storage at 4°C, the same workers found a further increase in peroxide values over the non-irradiated meat, but these peroxide values were also found to be independent of dose. Peroxide oxygen, as well as hydroperoxide and hydroxyl free radicals produced by irradiation, are known to attack the double bond position of the unsaturated fatty acids in lipids. This eventually results in breakdown of the lipid and loss of double bond character (Simic *et al.*, 1979). Therefore, it would be expected that higher radiation doses would cause greater loss of double bonds and that this could be measured by a decrease in iodine value as a function of irradiation dose.

Again the data show that there is no measurable loss of double bonds or dependence on irradiation dose in the range 0–10 kGy. As shown in this report by the iodine values, beef lipids were the most saturated of the meat samples studied, whereas turkey breast lipids were the most unsaturated. It was expected (Simic *et al.*, 1979) that unsaturated lipids would be more prone to lipid breakdown by irradiation, but this was not the case here.

TABLE 1
Gamma Radiation Effect on the Peroxide Value (PV)[a] and Iodine Value (IV)[b] of Five Meat Lipids

Meat		*Dose (kGy)*				
		0	*0.943*	*2.83*	*5.66*	*9.43*
Pork	(PV)[c]	3.77 ± 3.70	5.05 ± 4.42	4.75 ± 3.00	4.62 ± 3.46	4.82 ± 3.36
	(IV)[c]	64.4 ± 5.31	67.0 ± 6.96	63.2 ± 5.27	67.4 ± 7.25	62.0 ± 1.98
Lamb	(PV)	1.38 ± 1.58	1.92 ± 1.93	2.41 ± 2.20	3.27 ± 3.24	3.54 ± 2.89
	(IV)	58.9 ± 1.45	58.0 ± 0.96	59.7 ± 1.01	60.8 ± 2.04	60.6 ± 0.51
Beef	(PV)	2.97 ± 1.18	3.83 ± 1.44	4.50 ± 2.00	3.57 ± 2.06	3.53 ± 2.48
	(IV)	48.7 ± 2.06	48.5 ± 3.90	48.8 ± 4.25	48.3 ± 3.37	49.4 ± 3.15
Turkey leg	(PV)	0.00 ± 0.00	2.20 ± 3.11	2.57 ± 2.35	6.17 ± 3.37	4.03 ± 3.65
	(IV)	83.4 ± 11.7	85.9 ± 6.97	88.6 ± 8.53	84.9 ± 9.43	82.8 ± 9.23
Turkey breast	(PV)	5.17 ± 7.05	6.83 ± 7.19	8.07 ± 6.85	6.80 ± 4.69	7.80 ± 4.26
	(IV)	95.2 ± 7.77	95.5 ± 4.56	97.6 ± 5.72	95.8 ± 8.88	95.5 ± 4.61

[a]Milliequivalents of peroxide per 1000 g sample.
[b]Grams of iodine absorbed per 100 g sample.
[c]Mean and standard deviation for three replicates.

Apparently, at the dose levels used there was insufficient irradiation to significantly alter the lipid composition among the meat samples. In a study on the irradiation of chicken (Maxwell & Rady, 1989), only slight changes were found by gas chromatography in the lipids after irradiation doses up to 10 kGy.

The concentrations (μmolar) of malonaldehyde in various meats as a function of irradiation dose are presented as a bar graph (Fig. 1). It is known that the presence of malonaldehyde in meat is indicative of oxidative damage to unsaturated lipids. It also is known that fresh raw meat may contain some malonaldehyde (Wilson *et al.*, 1976). As shown here, even at zero dose there was some malonaldehyde present in all the meat samples. The data are the mean values for triplicate determinations. Figure 1 seems to indicate a dose dependence of malonaldehyde production. Consequently, the raw data (15 points for each meat) were subjected to regression analysis (Helwig, 1978). Only turkey breast lipids had a significant response to dose. Turkey breast lipids had a Pearson correlation coefficient of 0.625 and a p value of 0.013 which implies that the regression slope does not equal zero. Pork, lamb, beef, and turkey leg had Pearson correlation coefficients less than 0.220 and p values greater than 0.431. Consequently, pork, lamb, beef, and turkey leg lipids appear to be independent of dose in the range 0–10 kGy. To determine whether turkey breast lipids are significantly different in producing malonaldehyde as a function of dose than the other types of meat lipids, the mean data at 10 kGy were subjected to the Q test (Youmans, 1973). No significant difference was found for turkey breast lipids at the 90% confidence level.

CONCLUSION

There appears to be very little reaction between meat lipids and gamma irradiation in the dose range 0–10 kGy. Peroxide and iodine values show no dependence on dose; malonaldehyde formation shows some dependence on dose for turkey breast lipids at the μmolar level, but no apparent muscle difference. There may be several explanations for these results. First of all, the irradiation was conducted on fresh trimmed meat which

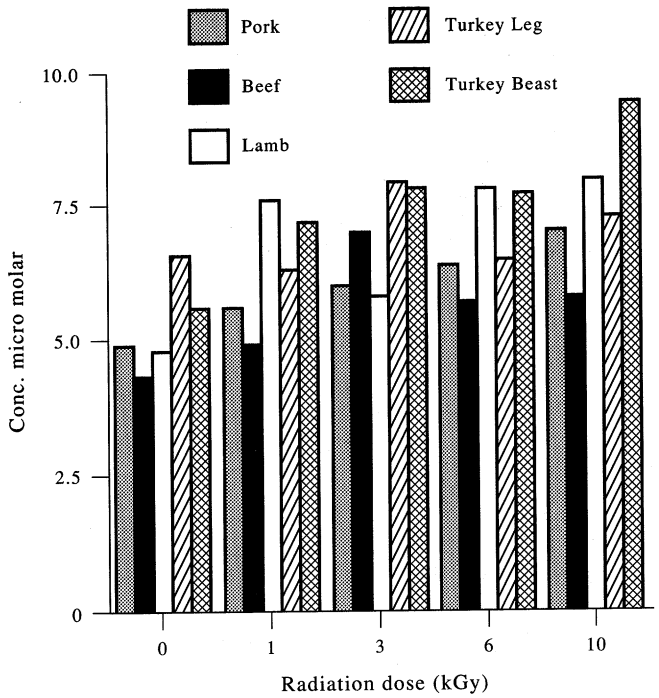

Fig. 1. Effect of gamma radiation on the production of malonaldehyde in pork, lamb, beef, turkey leg and turkey breast lipids.

incorporated a minimum of fat. It is known that autoxidation of unsaturated fats does not normally take place in animal cells because it is kept in check by the inhibitory action of antioxidants such as vitamin E and possibly vitamin C, and also by various enzymes, e.g. catalase (Lehninger, 1982). Secondly, the speed of analysis after irradiation may also have contributed to the low values obtained. Investigators at times have had meat samples irradiated at remote locations with significant delays between irradiation and analysis. Fatty peroxides are propagated by free radical chain reactions (Frankel, 1979). However, free radical chain reactions generally involve an induction period. Perhaps the analyses made in this work were within that induction period. It also should be mentioned that initially the aqueous layers in the extraction procedure were examined for peroxides. None were found. Future work might include a study involving storage of different types of irradiated meat muscles that was well beyond any possible induction period.

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